TREE DOMESTICATION: THE AUSTRALIAN EXPERIENCE IN PARTNERSHIPS WITH SPECIAL REFERENCE TO THE ASIA-PACIFIC REGION

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Introduction

Broadly speaking, domestication is the process of taking a wild plant species and bringing it under management and cultivation. Humans have engaged in this process for several thousand years, mainly for food crops and ornamentals, and with varying degrees of effort. Among tree species, by far the most effort has been put into those species with edible parts, particularly to select better fruit and nut varieties. In the Solomon Islands alone, for example, several different varieties of nut have been selected and domesticated (Evans 1999), including *Canarium* (ngali nut, three species), *Barringtonia* (cut nut, three species), *Terminalia catappa* (beach almond), *Gnetum gnemon* and *Pandanus* (screw pine, several species and numerous varieties).

Domestication is a highly species-specific and, therefore, highly variable process. For the majority of multipurpose tree species, it may consist simply of identifying good seed sources and developing appropriate propagation and cultural practices. In widely planted and commercially important timber species, the full domestication process may involve the systematic sampling and characterization of genetic variation, development of optimal propagation and silvicultural techniques, and intensive breeding, including the use of molecular genetics technologies and sometimes hybridization. Domestication seeks to bring out the maximum human benefit within a species as it is genetically refined from a wild tree to a cultivated plant. Figure 1 is a schematic representation of the domestication process.

Tree species play a critical role in human nutrition in the South Pacific and elsewhere in the tropics, and are vital genetic resources for food and agriculture. Although these values are well recognized in the work of international Future Harvest Centres such as ICRAF and IPGRI, and their national collaborators, trees that provide food crops have been largely excluded from international processes such as the Global Plan of Action and the revision of the International Undertaking on Plant Genetic Resources (see Thomson, Midgley, Boland & Whimp in these proceedings). In the South Pacific, serious concerns are now being raised about the erosion of genetic diversity in traditional subsistence food crops by land clearance for cash crops, climate change and an increasing reliance on Western convenience foods. Affected tree crops include well-known staples such as breadfruit (*Artocarpus* spp.) (Ragone 1997) and *Pandanus* in the northern Pacific (Muller & Velde 1999).

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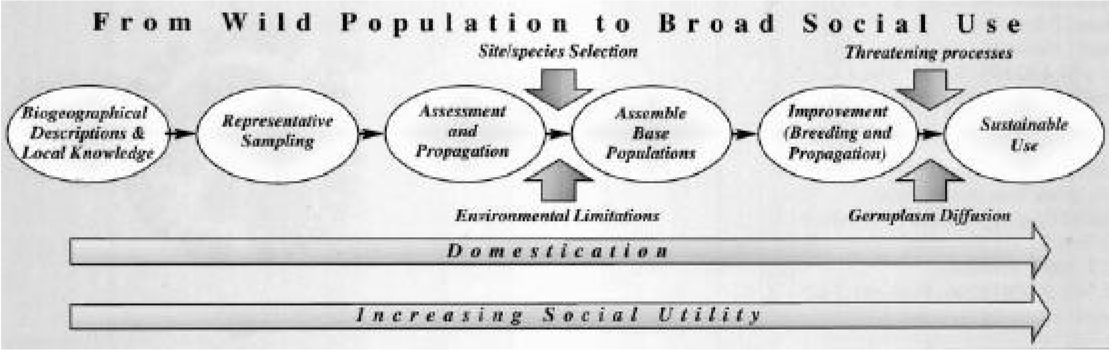

***Figure 1**. The process of tree domestication. Source: After Midgley (1995).*

This paper will focus on the domestication of forest trees for wood purposes, and in particular the role of CSIRO's collaboration in the Asia-Pacific region and its partnerships in this process. It is only in recent times, mainly during the 20th century, that domestication of timber trees has begun on any scale. Domestication is associated with massive reductions in the extent and availability of wood products from native forests, and the need to develop alternative plantation resources to provide timber and fibre for a growing global population (for example see FAO 1995).

Domestication work at CSIRO Forestry and Forest Products

Much of the current work of the Tree Improvement and Genetic Resources Programme at CSIRO Forestry and Forest Products (CSIRO FFP) is conducted within the context of species domestication. This allows for a fertile interdisciplinary approach which may involve ethnobotanists and social foresters (for rapid or participatory rural appraisals); eco-geographers and seed collectors (for exploration of genetic resources); seed technologists, propagation and nursery specialists (for germplasm storage and propagation); and operational tree breeders supported by quantitative and molecular geneticists, biometricians, physiologists, silviculturists, plant pathologists, entomologists and extension experts (for seed distribution and diffusion).

The Australian Tree Seed Centre (ATSC), in collaboration with its many research and development partners, has started to domesticate 70 species in 22 genera (see Appendix 1). An essential precursor to this work has been the assembly of biogeographic information on particular species and genera (e.g. Boland *et al*. 1984; Doran & Turnbull 1997). Such information has frequently been published in the form of monographs and annotated bibliographies (Pinyopusarerk 1990; Pinyopusarerk & House 1993; Thomson 1994a; Harwood 1989, 1998; Kalinganire & Pinyopusarerk 2000), and more recently in electronic formats such as the Electronic Forestry Compendium (CABI 2000) and the SPRIG Database of South Pacific Forest Genetic Resources.

The ATSC's tree seed collection activities and field assessments cover a wide range of species. For example, the ATSC currently stocks seed of about 1400 woody taxa (including species, subspecies and hybrids) in 169 genera; this includes 540 species of *Eucalyptus* and *Corymbia* and 350 species of *Acacia*. The majority of ATSC seed collections have been undertaken specifically for research and development purposes. Seedlots are well-documented, with many sampled as individual tree collections to enhance their usefulness to genetic research and tree improvement work.

Some of the species involved in domestication offer more promise than others, and this is reflected in increased effort and corresponding progress towards domestication objectives. Considerable advances have been made for the most important commercial wood species, such as *Acacia mangium*, *Eucalyptus camaldulensis*, *Eucalyptus globulus* and *Pinus radiata.* Our molecular genetics group has developed advanced research tools, such as genomic maps (for *A. mangium*, *P. radiata*, *E. globulus*, *Eucalyptus marginata* and *Eucalyptus nitens*) and marker-aided selection, as we seek to maximize community benefit from these species.

In addressing the challenges of domestication, we have established an extensive and effective network of research partners both in Australia and in most countries in the Asia-Pacific region. CSIRO FFP now has formal memoranda of understanding with partners in Vietnam, Thailand, Sarawak, Papua New Guinea and Indonesia, all of which foster research and domestication. In the main part of this paper we detail our partnership approach to domestication using the examples of *Acacia crassicarpa*, *Chukrasia* spp. and *Endospermum medullosum*.

Traditionally, the work of CSIRO FFP/ATSC and its predecessors has been in domestication of Australian tree species, especially *Eucalyptus*. This concern dates to the early 1960s when the Seed Section of the Forest Research Institute was first established by the Australian government to provide reliable, well-documented seed of *Eucalyptus* species in response to a request from the United Nations. Work on Australian tree species remains a strong focus. A recent example of our collaborative work on an Australian (and New Guinean) tree species is the domestication of *Acacia crassicarpa* in Southeast Asia. This tree has been described as being in the domestication 'fast lane' (Midgley 2000).

In recent times, with support from AusAID and ACIAR, we have become involved in applying our domestication approach more broadly to indigenous tree species in the Asia-Pacific region. This is in keeping with the expressed wishes of our partners, who are increasingly interested in growing local tree species for technical, social and environmental reasons. In this paper we discuss the example of *Chukrasia*, which is the current focus of our domestication work on indigenous tree species in Southeast Asia. This work is being conducted under the 'Development of Domestication Strategies for Commercially Important . This project, which is partly supported by ACIAR, links CSIRO FFP with partners in Lao PDR, Vietnam, Thailand and Malaysia. A valuable contribution from IPGRI has allowed us to include Myanmar in this network.

The third example we review is the domestication of the indigenous Pacific tree species *Endospermum medullosum*, a member of a genus of about 12 species extending throughout Southeast Asia into southern China. The work on *Endospermum* is being undertaken within the South Pacific Regional Initiative on Forest Genetic Resources or SPRIG Project (supported by AusAID), which links teams in five Pacific Island countries with those at CSIRO FFP and the Queensland Forestry Research Institute (QFRI). This project is about to begin a second phase of five years. Domestication of *Endospermum* during Phase 1 of SPRIG mainly involved a research partnership between the Vanuatu Department of Forests, QFRI and ourselves.

Acacia crassicarpa: a tree in the domestication fast lane

In its natural stands, *A. crassicarpa* (thick-podded salwood) is a moderately large tree growing up to 30m tall. Its natural growth and good form and vigour on poorly drained, slightly elevated, open grassland plateaux suggested a broader use in the humid tropics to those examining the potential for lesser-known species (Boland & Turnbull 1981; Turnbull *et al*. 1983). Over the past twenty years, *A. crassicarpa* has gone from a virtually unknown tree in the wilds of north Queensland and New Guinea to a major commercial plantation species for pulp and paper in Southeast Asia. Over 40,000ha of commercial plantations have now been established on the island of Sumatra in Indonesia (Midgley 2000). Although *A. crassicarpa* yields less pulp than the more widely-planted *Acacia mangium*, its high growth rate (mean annual increments are more than $25m^3$/ha/yr) maintains an acceptable yield of pulp per unit area. It is grown mainly on highly organic soils which have low pH and can occasionally become waterlogged, i.e. conditions in which *A. mangium* does not grow well.

A. crassicarpa is a good illustration of the potential for rapid domestication of fast-growing, early-flowering tropical tree species. Its domestication has involved substantial research and development work in Australia, Indonesia, Malaysia, Thailand, Vietnam and China. Much of the early work was done in ACIAR projects. Subsequent work has been carried out under the auspices of the Consultative Group for Research and Development of Acacia (COGREDA), national institutes and, most recently, the private sector.

In 1980 the species was of negligible commercial importance in native forests, It was known best by botanists and ecologists, through close association with its better-known cousins, *A. mangium* and *Acacia auriculiformis*. The first seed collections of *A. crassicarpa* destined for forestry research were collected for the ATSC in north Queensland in 1981. Overseas collaborators in FAO’s Forestry Department and Danida shared an enthusiasm for the potential of tropical acacias as reforestation species. In 1982 they supported joint ATSC/Forest Research Institute of Papua New Guinea missions to complete collections of *A. crassicarpa* in Australia and Papua New Guinea (Turnbull *et al*. 1983). A number of major ATSC collections of a suite of tropical acacia species followed over the next ten years with support from both AusAID and ACIAR (Gunn & Midgley 1991). These included the first collections of *A. crassicarpa* from Irian Jaya (Samlleberr) in 1990, the product of collaboration with the Indonesian Department of Forestry (Vercoe & McDonald 1991). Landowners and managers in Queensland and Papua New Guinea were very supportive of this early exploratory work. In Papua New Guinea the Department of Forests (now National Forest Service) actively collaborated in the field work and made the collections possible.

Interest in *A. crassicarpa* grew rapidly once high-quality, source-identified seed became available from natural provenances. Species and provenance trials in Thailand clearly demonstrated the outstanding growth potential of provenances from Papua New Guinea, with early height growth rates of 5m per year being recorded at Sai Thong (Pinyopusarerk 1989). By 1990, the ATSC had distributed over 500 research seedlots, primarily to research partners in Southeast Asia and China, many of whom were CSIRO partners in ACIAR-supported initiatives. In the early 1990s, CSIRO FFP and Chinese colleagues published the first report on the pulping and paper-making qualities of *A. crassicarpa* (Clarke *et al*. 1991). By 1993 the species had demonstrated excellent survival and vigour in trials across a range of sites in the humid tropics, and was recorded by COGREDA as the third most important tropical acacia in Southeast Asia (Awang & Taylor 1993). Trials have demonstrated its suitability for shallow sandy soils (Sim Boon Liang & Gan 1988), peaty soils and the clear superiority of the Papua New Guinean provenances (Chittachumnonk & Sirilak 1991; Minquan & Yutian 1991).

The continuing interest in *A. crassicarpa* and related species, and the positive results from a large body of research, provided the impetus to compile an annotated bibliography (Thomson 1994a) as part of AusAID’s support to CSIRO and the UNDP/FAO Regional Forest Tree Improvement Project (FORTIP). Shortly afterwards, the ATSC began a thorough taxonomic revision of the *Acacia aulacocarpa* group. This study has resulted in the recognition of the *A. crassicarpa* sub-group and the description of two highly promising species, *Acacia peregrina* (comprising the Papua New Guinean populations of *A. aulacocarpa* sens. lat.) and *Acacia midgleyi* from the far north of Queensland (McDonald & Maslin 2000). Provenance variation in economically important wood properties has recently been demonstrated in Malaysia (Shukor *et al*. 1998). The same study identified Samlleberr (Irian Jaya) and Olive River (north Queensland) as the most promising sources of seed for industrial plantations. Scientists at the University Putra Malaysia have recently completed studies of genetic diversity using molecular markers. CSIRO research partners in Thailand, Vietnam and Philippines have established seed orchards.

It is only 16 years since the first species and provenance trials of *A. crassicarpa* were established. In this short space of time, the natural variation within the species has been assessed, breeding programs started, molecular marker technologies established, taxonomy clarified, silvicultural studies completed and wood and fibre properties determined. Such rapid progress in domesticating a tree species is remarkable.

Given current world prices for kraft pulp, the 40,000ha plantation resource of *A. crassicarpa* on Sumatra represents a national asset of more than US$1 billion (Midgley 2000). It offers opportunities for employment and economic development for many Indonesians, and industrial opportunities for larger companies. The plantations are the product of a great deal of collaborative work between scientists and managers in many companies and research institutes and CSIRO. Supporting organizations such as ACIAR, AusAID, Danida, FAO and USAID/FFRED can be justifiably pleased with the results of their support to Asian research partners, partners in Papua New Guinea and CSIRO, and with the collaboration that this has engendered. The seed orchards being developed by CSIRO and partners will greatly increase the availability of high quality germplasm and enhance its uptake (Harwood 1999).

What is the future for domestication of *A. crassicarpa*? Given the established economic importance of this species, it is likely that much of the future domestication of *A. crassicarpa* will be undertaken in the private sector, both by large pulp corporations and by smaller growers. The short generation times of this species make it amenable to rapid tree improvement, for example for better pulp characteristics. The species is closely related to other commercially important *Acacia* species, and there is potential for intra-specific hybrids with *A. auriculiformis*, *A. peregrina*, *A. mangium* and *A. midgleyi* to improve certain attributes or perhaps capture heterosis for growth as observed in the *A. auriculiformis* x *A. mangium* hybrid in Vietnam. In drier regions, *A. crassicarpa* puts a large amount of photosynthate (and nutrients) into heavy, woody fruit crops after 3–4 years. The creation of sterile lines, for example triploids, as in the approach of the Pacific Australia Reforestation Company, may maintain growth rates and wood production in sexually mature trees, as well as increase stress tolerance and minimize any tendency for weediness.

The tree has outstanding, but largely untapped, potential for other difficult sites in Southeast Asia. These include planting above saline seeps in Tung Kula Ronghai, northeast Thailand, for groundwater recharge control; and reforestation of acidic, infertile sands with seasonal waterlogging and shallow hardpans in Thua Thien Hue Province, central Vietnam (Thomson 1994b). *A. crassicarpa* also has potential for agroforestry and is now being grown for fuelwood in woodlots by 3000 farmers in Tabora district, Tanzania, following its introduction by ICRAF in 1988.

It is likely that several generations of selection from a broad genetic base will lead to the development of better-adapted land races for specific, difficult or unusual sites. In this context the experience of the Centre Technique Forestière Tropicale (now CIRAD Forêt) in Senegal with *Acacia tumida* (another species in the section Juliflorae) is interesting. Progeny of first-generation seedlots from northern Australia exhibited highly variable performance with survival rates of only about 50%. After several generations of collection and propagation of seed from survivors, a vigorous line with almost 100% survival was developed (M. Cazet pers. comm.).

Chukrasia

Chukrasia is a commercially important indigenous timber genus in South and Southeast Asia. Trees can be propagated without difficulty from seed as well as vegetatively by stem cuttings. *Chukrasia* is moderately fast growing and has well-established timber markets in the region. Although *Chukrasia* was nominated as a priority genus for plantation forestry and genetic conservation in Vietnam, Lao PDR, Malaysia and Thailand (Anon 1996), it has not been investigated in depth or subjected to any improvement until recently. *Chukrasia* was also thought to be understood taxonomically and its natural distribution reasonably well known. For these reasons, CSIRO selected *Chukrasia* for the development of a model domestication strategy in ACIAR project FST/96/05. The partners in this project are:

- Forest Science Institute of Vietnam
- National Agriculture and Forestry Research Institute of Lao PDR
- Royal Forest Department of Thailand
- Forest Research Institute Malaysia
- CSIRO Forestry and Forest Products

Seed has been supplied to the project from forestry research collaborators in other Asian countries, including China, India, Indonesia, Myanmar and Sri Lanka. The *Chukrasia* research project has followed closely the steps in the domestication process outlined in Figure 1. To date, the following work has been carried out:

- **Review existing information on *Chukrasia*, including unpublished sources**. This work was started before the project commenced in January 1999. It resulted in a monograph by Kalinganire and Pinyopusarerk (2000).

- **Eco-geographic survey to ascertain the present distribution of *Chukrasia*, especially in partner countries**. This work was started before the project commenced and is still continuing. Findings from some countries were reported at a project inception meeting held in Thailand in February 1999. All available information has been summarized in the *Chukrasia* monograph (see above).

- **Assemble *Chukrasia* germplasm for research and development work, including seed collections in partner countries and procurement from elsewhere**. This work was started before the project commenced and is still continuing. So far, seed has been collected or procured from 32 provenances (seedlots) in ten countries: China, India, Lao PDR, Malaysia, Myanmar, Thailand, Vietnam, Sri Lanka and Indonesia and Australia (naturalized).

- **Propagation-related research**. Seed storage trials at ATSC have revealed that seed can be safely stored for more than three years. These findings contradict earlier reports, which suggested a short period of viability (Pinyopusarerk *et al*. 2001). Vegetative propagation studies have been conducted by the Research Centre for Forest Tree Improvement in Vietnam to investigate factors affecting rootability of *Chukrasia* cuttings. These studies have yielded encouraging findings, with even mature trees (10–20 years old) giving rooting rates of 70% when treated with 1% indolebutyric acid (Anon 2000). Together these findings on seed storage and vegetative propagation enhance the prospects of reliably establishing a given plantation area of *Chukrasia*.

- **Patterns of genetic variation in *Chukrasia*.** Genetic variation patterns are being investigated for quantitative traits (through seedling morphology studies and provenance trials) and molecular traits (isozyme studies). A seedling morphology study has been completed (Kalinganire *et al*. in prep.). Using leaf and bark characters, this study revealed the existence of three distinctive groups corresponding to *Chukrasia tabularis* (smooth bark), *Chukrasia* aff. *velutina* (rough corky bark) and a hitherto unknown entity from Sri Lanka (Figure 2). Provenance trials have been started in all partner countries and also in Sri Lanka. These trials are already revealing interesting differences in growth and performance; for example, plants of the *C. tabularis* type are more cold tolerant (in northern Vietnam) than those of *C.* aff. *velutina*. One objective of the field trials is to identify superior provenances for specific sites. Detailed shoot borer (*Hypsipyla robusta*) assessments are to be undertaken in the field trials.

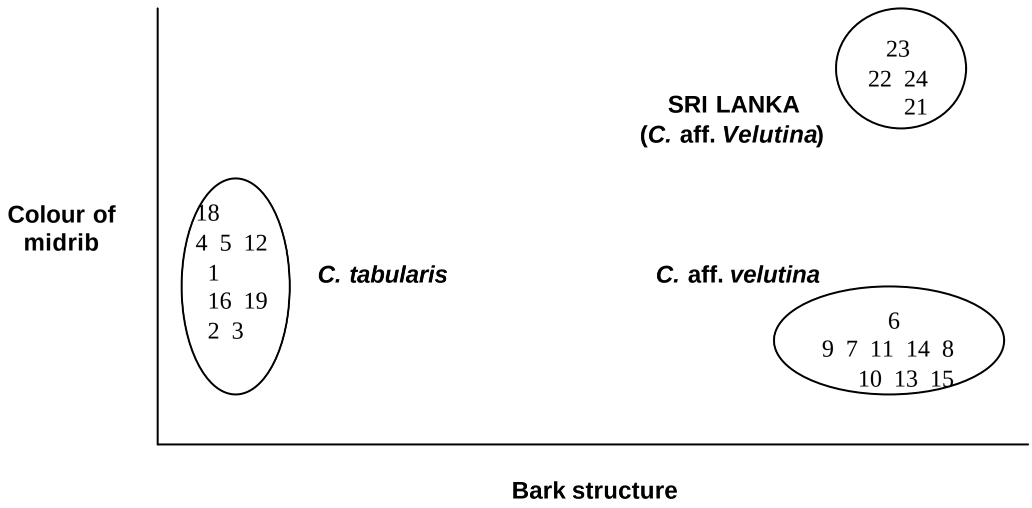

Figure 2. *Plot of colour of midrib and bark structure following principal component analysis of 24 variates assessed in a Chukrasia seedling morphology study. Source: Kalinganire et al. in prep.*

The main problems encountered to date have been biological and technical; for example, severe drought in Thailand caused high mortality in some field experiments. Although genetic conservation has been an additional objective of the project, only one small provenance resource stand has been established in Lao PDR, and another is planned in Malaysia. This is partly because excess planting stock was used to establish additional field trials in Thailand and Vietnam, and would appear to indicate that research partners currently place less emphasis on conservation goals. The ATSC maintains seed of 32 seedlots of *Chukrasia* which will be made available to collaborators for gene conservation or to establish seed stands or provenance resource stands of better-performing provenances.

The extent to which *Chukrasia* domestication work can be sustained may vary between countries depending on their available resources and the importance they attach to the species.

Endospermum medullosum (whitewood)

In keeping with the project's focus on indigenous species, *E. medullosum* has been selected as a top priority species for domestication by Vanuatu under SPRIG. *Endospermum* is a genus belonging to the Euphorbiaceae family. The genus is distributed from southern China through Southeast Asia, New Guinea into northern Australia, and east through Solomon Islands and Vanuatu to Fiji. *E. medullosum* is a timber species distributed from West Papua (Indonesia) through Papua New Guinea, Solomon and Santa Cruz Islands to Vanuatu. Its timber is widely used locally, especially in preservative-treated form, and it has an established export market in East Asia, where it fetches more than US$1000/$m^3$ for sawn, kiln-dried boards. It is highly regarded for mouldings and the pale colour of the wood lends itself well to staining. The tree grows very fast when young, and is well adapted to tropical cyclones and resistant to *Phellinus noxious* (brown root rot). It appears to have excellent plantation potential in the South Pacific region.

Both the Vanuatu Department of Forestry and private sawmills have been replanting this species, and the Department has ranked provenance trials of this species as a high research priority. Before the work by SPRIG, little was known of the silviculture of this species, with the exception of preliminary vegetative propagation studies by the Queensland Forestry Research Institute and Melcoffee Sawmills on Santo, Vanuatu. This early research had shown that the species was amenable to vegetative propagation from juvenile material (up to 2–3 years old).

The main steps in the domestication of whitewood in SPRIG have been as follows:

- **A comprehensive literature review and eco-geographic survey of the species**. The survey was undertaken during 1997. It documented information on taxonomy and related species, botanical characteristics and phenology, distribution, use, silviculture, management, protection, variation and breeding (Thomson & Uwamariya 1998).

- **A community forest genetic resources survey**. Twenty-six village communities on 12 islands throughout Vanuatu were surveyed during 1997 to document local knowledge and use of whitewoods (Siwatibau *et al*. 1998). This information was used to assist in planning seed collections and developing a species conservation strategy.

- **Country-wide seed collections of whitewood in Vanuatu**. Seed collections were made by the Department of Forestry and SPRIG during March and April 1998. Seed was collected from 144 individual trees on seven islands. The most northerly populations in the Banks Group could not be sampled because of cyclones. New seed-collecting practices were developed, including a throwing rope technique highly suited to this species, which has brittle branches and is dangerous to climb. High proportions of collected fruits were infested with the larvae of a small wasp, *Syceurytoma* sp. Freshly collected wasp-infested seed was readily separated by immersion in water.

Viable seeds sink immediately, whereas wasp-infested seeds float and should be discarded.

- **Provenance/progeny trials**. More than 8ha of trials of diverse genetic material of *Endospermum* were established at Shark Bay Field Research Station in Santo, Vanuatu, in December 1998 and January 1999. These will provide detailed information on the pattern of genetic variation in whitewood and serve as gene conservation and seed stands. After one year, the main highlights of this work are as follows (Viji *et al*. 2000):

  - The main family trial has high survival rates and rapid early height growth, with plants averaging 2.5m. There are small differences in early height growth between provenances and families of *E. medullosum* from Vanuatu (average family heights range from 2m to 3m).
  - The faster growing Vanuatu sources are from South and East Santo, and these are most threatened by over-exploitation and changes in land use.
  - Three Papua New Guinea seedlots (all from near Popondetta, Oro Province and collected as *E. medullosum*) have shown exceptional early height growth (range 3.4–3.6m), and are about one metre faster than Vanuatu sources. The Papua New Guinea seedlots exhibit several different morphological characteristics, and appear to represent a different species, thought to be closely related to *Endospermum myrmecophilum*.

- **Clonal hedges and vegetative propagation experiments**. These were conducted for whitewood in 1998 (Anon 1999). One experiment involved decapitating young trees to rejuvenate the plants. This proved to be a risky procedure, with coppicing ability varying with season.

- **A conservation and sustainable management strategy**. A conservation strategy for whitewood was developed by the Department of Forestry during 1998 and 1999 in consultation with key stakeholders (Corrigan *et al*. 1999). The strategy has been divided into priority actions to be undertaken according to the available resources. During the field work to develop the strategy, a new population of *E. medullosum* was identified in Erromango, thus extending its southerly range by more than 100km.

The prospects for rapid breeding of this species appear to be excellent given that: i) the projected rotation period is about eight years and trees flower and fruit at an age of about 3–4 years (i.e. about half-rotation length and by which time meaningful selections can be undertaken); and ii) flowers and fruits are borne on separate male and female trees, ensuring out-crossing and the development of hybridizing seed orchards.

One local sawmill, Melcoffee Pty Ltd, is continuing its own research and development on the species, including spacing and pruning trials, comparison of performance of vegetatively and seedling-propagated plants, and technologies for finger jointing and glue-lamination of boards from juvenile planted material (3–4 years old). The prospects for further domestication and extensive planting of this species appear to be exceptionally good.

Lessons learned and conclusions

The main lessons from our domestication work are as follows:

- Selection of species to work on is critical. Decision-making must be an inclusive process of interested parties, especially if it is to ensure that the most promising species are worked on. It is vital that the species either is already widely planted or has this potential. Certain biological characteristics will speed up the domestication and improvement process, for example high levels of intra-specific variation, rapid early growth, early flowering and seed set, ease of propagation (including vegetative propagation) and a short rotation. Slower-growing species with inherently good wood properties should not be excluded from consideration in longer-term programmes.

- For developing countries, greater benefits will accrue from working on the early phases of domestication of a greater number of promising species, than from a focus on intensive or sophisticated tree breeding of a single or few species. This is because, firstly, the greatest single-step gains in improvement arise from selection of the best provenance or seed source (witness the superior performance of Papua New Guinea provenances of *A. crassicarpa* compared with those from north Queensland). Secondly, tropical tree growers are increasingly interested in growing a larger number of species, often in mixtures, for a wide range of end products and services.

- Greater attention is being paid to domestication of indigenous species. These have several potential advantages over exotics, including:

  - Their characteristics are known to local people, especially their capability to provide certain products, and they tend to be more readily accepted;
  - Proven adaptation to local conditions; and
  - Greater contribution to biodiversity conservation values.

  Exotic species, however, will remain important in situations where environments have become highly modified, for example agricultural production systems and highly degraded sites, and where the objective is to maximize productivity and commercial returns.

- The greatest progress in domesticating tree species will be made through a multidisciplinary, collaborative approach involving biological and social sciences.

- The involvement of research and development partners in all phases of the domestication process, including provision of appropriate formal and practical training, has greatly enhanced the prospects for sustaining the domestication work we describe here, and for extending it to other species.

- High levels of trust and goodwill are needed between forestry research organizations with access to different parts of the natural range of shared species. These are evident in the development work on *A. crassicarpa*, which was made possible only by the good and close ties between the Forest Research Institute of Papua New Guinea and CSIRO. They are also evident in the generous support from national forestry agencies for the seed collections of *Chukrasia*.

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***Appendix 1**. Tree species in the process of domestication with CSIRO Forestry and Forest Products and networks in Australia and overseas. Asterisks indicate trees that are exotic to the particular region.*

Australia	Asia	South Pacific & Papua New Guinea	Africa
Acacia auriculiformis	*Acacia auriculiformis*	*Asteromyrtus symphyocarpa*	*Acacia colei**
Acacia mangium	*Acacia cincinnata**	*Calophyllum euryphyllum*	*Acacia difficilis**
Acacia mearnsii	*Acacia crassicarpa*	*Canarium indicum*	*Acacia elachantha**
Acacia peregrina	*Acacia difficilis**	*Casuarina oligodon*	*Acacia holosericea**
Backhousia citriodora	*Acacia mangium*	*Dracontomelum dao*	*Acacia torulosa**
Corymbia henryi	*Acacia mearnsii**	*Endospermum macrophyllum*	*Casuarina equisetifolia**
Corymbia maculata	*Acacia peregrina*	*Endospermum medullosum*	*Casuarina junghuhniana**
Corymbia variegata	*Acacia* hybrids*	*Endospermum robbieanum*	*Eucalyptus camaldulensis**
Eucalyptus benthamii	*Casuarina cunninghamiana**	*Pleiogynium timorense*	*Grevillea robusta**
Eucalyptus camaldulensis	*Casuarina equisetifolia*	*Pometia pinnata*	
Eucalyptus cladocalyx	*Casuarina junghuhniana*	*Pterocarpus indicus*	
Eucalyptus delegatensis	*Chukrasia* aff. *Velutina*	*Santalum album**	
Eucalyptus dunnii	*Chukrasia tabularis*	*Santalum austrocaledonicum*	
Eucalyptus globulus	*Chukrasia* sp. nov. (Sri Lanka)	*Santalum macgregorii*	
Eucalyptus grandis	*Eucalyptus brassiana**	*Santalum yasi*	
Eucalyptus nitens	*Eucalyptus camaldulensis**	*Swietenia macrophylla**	
Eucalyptus occidentalis	*Eucalyptus pellita*	*Terminalia catappa*	
Eucalyptus pellita	*Eucalyptus tereticornis*	*Terminalia richii*	
Eucalyptus polybractea	*Eucalyptus urophylla*	*Toona ciliata*	
Eucalyptus radiata	*Eucalyptus* hybrids*		
Eucalyptus regnans	*Grevillea robusta**		
Eucalyptus sideroxylon	*Melaleuca cajuputi*		
Eucalyptus tricarpa	*Melaleuca leucadendron*		
Eucalyptus urophylla	*Styrax tonkinensis*		
Grevillea robusta			
Leptospermum petersonii			
Melaleuca alternifolia			
*Pinus brutia**			
*Pinus pinaster**			
*Pinus radiata**			
Toona ciliata			